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Association of the Korean Healthy Eating Index and sleep duration with prediabetes in middle-aged adults

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Conflict of Interest
The authors declare no potential conflicts of interests.

ABSTRACT

BACKGROUND/OBJECTIVES: Sleep duration and diet quality are reportedly associated with the risk of diabetes. This study aimed to examine the risk of diabetes according to sleep duration and diet quality in middle-aged Koreans.
SUBJECTS/METHODS: Using the Korea National Health and Nutrition Examination Survey 2019–2020, raw data from 2,934 participants aged 40–64 yrs (1,090 men and 1,844 women) who were not diagnosed with type 2 diabetes were analyzed. With a sleep duration of 7–7.9 h per night as the referent category, diet quality was assessed using the Korean Healthy Eating Index (KHEI), which comprises adequacy, moderation, and energy balance.
RESULTS: The study results showed that individuals with a short sleep duration had significantly higher blood glucose ($P = 0.034$) and HbA1c levels ($P < 0.001$) than those had by individuals with a sleep duration of 7–7.9 h. Within the group with a sleep duration of 7–7.9 h, the lowest quintile of the KHEI score had a significantly higher risk of prediabetes than that had by the highest quintile of the KHEI score (Model 1: odds ratio [OR], 1.775; 95% confidence interval [CI], 1.072–2.939; $P < 0.05$ and Model 2: OR, 1.731; 95% CI, 1.040–2.882; $P < 0.05$).
CONCLUSION: Our findings suggest that achieving the sleep duration of 7–7.9 h and eating good diet are associated with the lowest risk of prediabetes. We recommend that the results of this study be used to educate adults aged 40–64 yrs on diet and lifestyle habits to prevent diabetes.

Keywords: Healthy Eating Index; sleep duration; prediabetes; adult

INTRODUCTION

Insufficient sleep duration has been reported to increase the risk of various chronic diseases such as cardiovascular diseases, type 2 diabetes, obesity, hypertension, and metabolic syndrome [1-5]. Moreover, according to Svensson *et al.* [6], sleep duration has a J-shaped relationship with all-cause mortality risk that varies by age and sex. While there is a growing emphasis on the importance of sleep for health outcomes, sleep disorders and deprivation are increasingly prevalent under the influence of social factors, such as globalization, technology, and public policy [7].

Author Contributions

Conceptualization: Kim JM, Bae YJ; Formal analysis: Kim JM; Investigation: Kim JM; Methodology: Kim JM; Supervision: Bae YJ; Writing - original draft: Kim JM, Bae YJ; Writing - review & editing: Kim JM, Bae YJ.

The National Sleep Foundation [8] recommends an adequate sleep duration of 7–9 h for young adults and adults, and the Center for Disease Control and Prevention also suggests a minimum of 7 h sleep per night for adults [9]. However, insufficient sleep is common among Koreans, as the mean weekday sleep duration for Korean adults aged 19 yrs and above is 6.7 h, which is below the recommendations [10]. The prevalence of diabetes has been continuously increasing among Koreans. In 2020, the prevalence of diabetes among Korean adults aged 30 yrs and above was 16.7%, marking a significant 41.5% increase from 11.8% in 2012 [11]. In addition, 44.3% of this population had a prediabetic status, with prevalence rates of 30.5%, 40.7%, 50.6%, 49.6%, and 49.6% among individuals in their 30s, 40s, 50s, 60s, and 70s and above [11]. As the risk of diabetes and pre-diabetes increases among adults, an in-depth study is needed to identify risk factors associated with diabetes in adults aged 40 yrs or older who are at risk of pre-diabetes and type 2 diabetes [12].

The significant role of sleep in glycemic control and metabolism has been largely reported. Since the findings of Spiegel *et al.* [13] in 1999 regarding the negative impact of sleep debt on carbohydrate metabolism and endocrine function, many studies have reported a U-shaped relationship between sleep duration and type 2 diabetes [14-16]. Although the mechanisms underlying the relationship between total sleep duration and type 2 diabetes have not been fully elucidated, glucose tolerance and tryptophan concentration have been reported to decrease with sleep debt, whereas evening cortisol secretion increases, leading to increased insulin resistance [13]. Furthermore, sleep deprivation alters the metabolism of adipose tissue because sleep curtailment reduces Akt phosphorylation in adipocytes, indicating insulin resistance [17].

The effect of diet on sleep has also been reported. Short sleep duration has been shown to be associated with increased total energy and fat intake, while evidence of associations between short sleep duration, reduced fruit consumption, and a lower quality diet remains limited [18]. Furthermore, regarding the interrelationship between sleep, diet, and glycemic control, the dietary composition affecting glycemic control is also related to sleep, suggesting that dietary manipulations, particularly regarding carbohydrate quality, can aid sleep [19]. The relationship between sleep and diet is very complex, with multifaceted effects on glucose metabolism. The regulation of sleep duration can affect the intake of high-calorie and high-carbohydrate meals, while the quantity and quality of carbohydrate intake can influence sleep [20,21]. Additionally, a previous study found that the combined effects of diet patterns, sleep patterns, and glycated hemoglobin (HbA1c) were related to body mass index (BMI) [22]. However, the research needed to draw a consistent conclusion about the effects of the relationship between sleep and diet on diabetes-related indicators is insufficient. Since studies on the relationship between sleep-diet factors and diabetes have been limited to association analyses in patients with diabetes, few studies have examined the relationship between sleep-diet factors and prediabetes. Therefore, this study aimed to investigate the relationship between sleep duration, dietary quality, and the risk of prediabetes in middle-aged adults, given the sharp increase in the prevalence of prediabetes.

SUBJECTS AND METHODS

Study population

This study utilized data from 4,828 adults aged 40–64 yrs old among the participants of the 8th Korea National Health and Nutrition Examination Survey (KNHANES VIII-1,2) (2019–

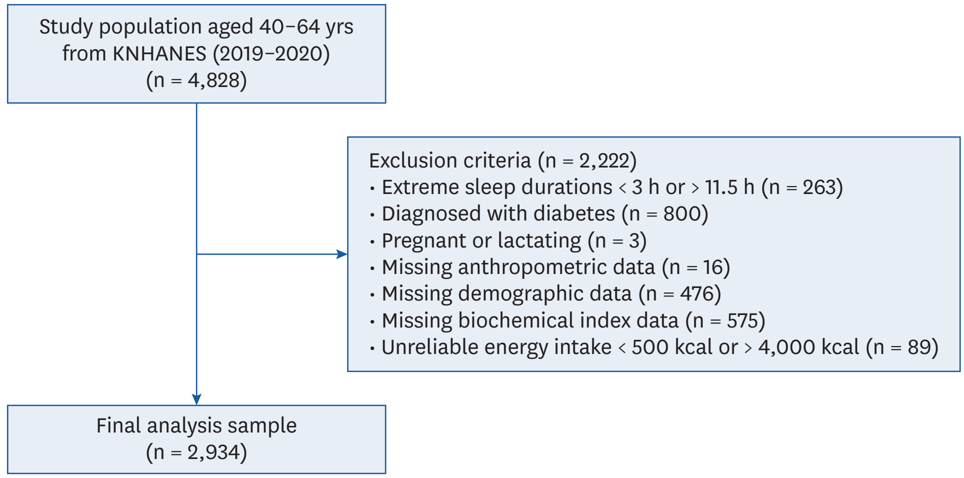

Fig. 1. Flow chart of participant enrollment.
KNHANES, Korea National Health and Nutrition Examination Survey.

2020). The KNHANES is a complex, stratified, multistage probability and cluster survey conducted throughout the year, using a rolling method to sample participants representing the Korean population. The KNHANES has a cross-sectional design and consists of health interviews, examinations, and nutritional surveys. Its details are described in a study by Kweon *et al.* [23]. Among the 4,828 middle-aged adults, data from participants who met the following criteria were excluded from the analysis: 1) those with extreme sleep durations of less than 3 h or more than 11.5 h on weekdays (n = 263) [24]; 2) those diagnosed with diabetes (n = 800); 3) those who were pregnant or lactating (n = 3); 4) those without height and weight values (n = 16); 5) those without values for basic demographic variables such as age, sex, and residential area (n = 476); 6) those without biochemical index values such as blood sugar, HbA1c, and insulin levels (n = 575); and 7) those with unreliable total energy intake of less than 500 kcal or more than 4,000 kcal per day (n = 89) [24]. Following the exclusion, data from 2,934 people (1,090 men and 1,844 women) were included in the analysis (**Fig. 1**). The 2019–2020 KNHANES was conducted with the approval of the Research Ethics Review Committee of the Korea Center for Disease Control and Prevention (KCDC) (IRB approval numbers: 2018-01-03-C-A, 2018-01-03-2C-A), and all participants provided informed consent.

General measurements

Sociodemographic variables, such as age, sex, education level, occupation, and household income, were assessed using a self-administered questionnaire. Information regarding smoking habits, alcohol use, physical exercise, sleep duration, obstructive sleep apnea, stress levels, and subjective health status was obtained through interviews on health and behavior. Education level was classified as elementary school, middle school, high school, college or higher. Marital status was divided into married and single categories. The occupation was classified based on whether an individual was employed or unemployed. Household income levels were segmented into four groups: low, middle-low, middle-high, and high. Smoking was recorded as current smoker or not (former smoker or never smoked). Alcohol intake was noted as either drinking (≥ 1 drink/month in the past year) or not drinking. Physical activity was categorized based on intensity and duration: active (engaging in mid-intensity exercise for more than 2.5 h per week or high-intensity or mixed intensity exercise for over 1.25 h per week, with 1 min of high-intensity equivalent to 2 min of mid-intensity) or inactive, following

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the KNHANES standards set by the KCDC [25,26]. Stress was classified as very high, high, low, or rare. Sleep duration was categorized as < 6 h, 6–6.9 h, 7–7.9 h, or ≥ 8 h [24].

Physical measurements and blood analysis

Health status data included variables related to physical examinations and blood tests. BMI was calculated as weight divided by height squared (kg/m^2) and was used to classify the participants into four weight categories: underweight (BMI < 18.5 kg/m^2), normal weight (18.5 ≤ BMI < 23 kg/m^2), overweight (23 ≤ BMI < 25 kg/m^2), or obese (BMI ≥ 25 kg/m^2) [27]. Blood glucose, HbA1c, and insulin levels were measured using hexokinase (Labospect 008AS; Hitachi, Tokyo, Japan), high performance liquid chromatography (Tosoh G8; Tosoh, Tokyo, Japan), and electrochemiluminescence immunoassay (Modular E801; Roche, Mannheim, Germany). The homeostasis model assessment of insulin resistance (HOMA-IR) was used to evaluate insulin resistance (Fasting Serum Glucose [mg/dL] × Fasting Insulin [μIU/mL]/405) [28]. Prediabetes was defined as fasting blood glucose between 100 to 125 mg/dL or 5.7% ≤ HbA1c ≤ 6.4% [29].

Dietary intake and quality assessment

Dietary data were collected through a dietary survey conducted by professional dietitians using the 24-h recall method. The food groups were classified into 22 categories according to the food group classification criteria provided in the KNHANES guidelines [25], and the total food intake and food group intake per 1,000 g of total food intake were calculated. The total energy and nutrient intake were estimated from these data using a standard food composition table [30]. Evaluations included total daily energy consumption, the proportion of calories derived from macronutrients (carbohydrates [CHO], fats, and proteins), and nutrient amounts per 1,000 kcal consumed.

The Korean Healthy Eating Index (KHEI), a tool developed by the KCDC, measures compliance with national dietary guidelines and assesses dietary lifestyle and quality of life in Koreans [31]. The KHEI comprises 14 components across three categories: eight components measure the adequacy of consuming recommended foods and nutrients (such as breakfast regularity and intake of multi-grains, various types of fruits and vegetables, meat, fish, eggs, legumes, milk, and dairy products), three components assess moderation in consuming certain foods and nutrients (specifically, the percentage of energy intake from sweets and beverages, saturated fats, and sodium), and three components measure the balance of energy intake (proper energy intake and the percentage of energy intake from CHO and fats). The maximum score for the KHEI is 100, with components related to multi-grains, fruits, vegetables, CHO and fat energy percentage, and adequate energy intake, which is assigned a value of 5 points due to their significance, while other components are valued at 10 points as outlined in the KNHANES raw data.

Statistical analysis

Statistical analyses were conducted using SAS version 9.4 (SAS Inc., Cary, NC, USA), applying a complex survey design that included multistage, stratified, and clustered sampling, along with sample weights. Continuous variables such as age, BMI, blood profiles, food group intake, total energy consumption, nutrient consumption, and KHEI scores are presented as means ± SEs. Categorical variables including sex, education level, occupation, household income, alcohol intake, smoking, physical activity, stress, subjective health status, BMI category, obstructive sleep apnea, and prediabetes, are expressed as weighted percentages and SEs. Differences in sleep duration were compared using χ^2 tests and a general linear model, and the Dunnett's test adjusting for age and sex was performed as a post hoc analysis.

To examine the association between sleep duration, KHEI score quintiles, and prevalence of prediabetes, odds ratios (ORs) and 95% confidence intervals (CIs) were estimated using logistic regression models. Age, sex, education level, occupation, household income level, perceived stress, BMI, and total energy intake, which exhibited significant differences according to sleep duration, were included as covariates. Model 1: Adjusted for age and sex in the total participants, or for age in sex-stratified analyses. Model 2: Further adjusted for household income, education level, occupational status, stress, BMI, and total energy intake in addition to the variables in Model 1. Model 3: Additionally, adjusted for KHEI score within sleep duration categories or for sleep duration within KHEI score quintiles, based on the adjustments in Model 2. Statistical significance was set at $P < 0.05$.

RESULTS

General characteristics of the participants

Table 1 shows the sociodemographic characteristics of the participants according to sleep duration. The mean age of the participants was 51.25 ± 0.20 yrs in this study, with no significant differences between groups. The proportion of women in the ≥ 8 h sleep duration group was highest at 61.34%, and the proportion of men in the 6–6.9 h sleep duration group was highest at 48.45%, showing a significant difference between the groups ($P = 0.010$). For household income, the proportion of individuals with high income was the highest at 44.49% in the 7–7.9 h sleep duration group, and the proportion of individuals with low income was the highest at 11.79% in the < 6 h sleep duration group, showing a significant difference between the groups ($P = 0.001$). Regarding education level, the proportion of college graduates or higher was highest at 53.66% in the 7–7.9 h sleep duration group, and the proportion of individuals with elementary school education or lower was highest at 8.26% in the < 6 h sleep duration group, showing a significant difference between the groups ($P < 0.001$). Regarding occupational status, the proportion of employed participants was highest in the 6–6.9 h sleep duration group at 75.50%, while the proportion of unemployed participants was highest in the ≥ 8 h sleep duration group at 39.49%, showing a significant difference between the groups ($P < 0.001$). Regarding subjective health status, the 6–6.9 h sleep duration group had the highest rate of good health at 31.33%, and the rate of bad health was highest at 17.15% in the < 6 h sleep duration group, showing a significant difference between the groups ($P < 0.001$). BMI was significantly higher in both the 6–6.9 h and < 6 h sleep duration groups than in the 7–7.9 h sleep duration group ($P < 0.001$). Obesity was highest at 42.63% in the < 6 h sleep duration group, and the normal rate was highest at 42.78% in the ≥ 8 h sleep duration group. In the ≥ 8 h sleep duration group, the proportion of individuals with almost no stress was highest at 15.55%, and in the < 6 h sleep duration group, the proportion of individuals with very high stress was highest at 7.75% ($P < 0.001$). The rate of prediabetes was lowest at 47.96% in the 7–7.9 h sleep duration group and highest at 60.58% in the < 6 h sleep duration group ($P < 0.001$). In terms of metabolic indicators, fasting glucose levels were significantly higher in the < 6 h sleep duration group (96.95 ± 0.50 mg/dL, $P = 0.034$) than in the 7–7.9 h reference group (95.49 ± 0.37 mg/dL). HbA1c levels were also significantly higher in both the < 6 h (5.63 ± 0.01%, $P < 0.001$) and 6–6.9 h (5.61 ± 0.01%, $P < 0.01$) sleep duration groups than in the 7–7.9 h reference group (5.57 ± 0.01%). Insulin levels and HOMA-IR values did not show significant differences across the groups; however, a significant increase in both insulin (9.06 ± 0.62 μIU/mL, $P < 0.05$) and HOMA-IR (2.21 ± 0.15, $P < 0.05$) was observed in the < 6 h sleep duration group compared to the 7–7.9 h reference group (7.64 ± 0.18 μIU/mL and 1.83 ± 0.05, respectively).

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Table 1. General characteristics of the participants according to sleep duration category

Variables	Sleep duration				Total (n = 2,934)	*P*-value
	< 6 h (n = 497)	6–6.9 h (n = 847)	7–7.9 h (n = 941)	≥ 8 h (n = 649)		
Age (yrs)	51.84 ± 0.36	51.32 ± 0.30	50.83 ± 0.28	51.31 ± 0.34	51.25 ± 0.20	0.113
Sex						0.010
Male	46.05 (2.52)	48.45 (1.83)	44.27 (1.88)	38.66 (2.15)	44.60 (1.01)	
Female	53.95 (2.52)	51.55 (1.83)	55.73 (1.88)	61.34 (2.15)	55.40 (1.01)	
Household income						0.001
Low	11.79 (1.65)	6.14 (0.94)	6.28 (0.89)	9.00 (1.40)	7.75 (0.66)	
Middle-low	25.08 (2.32)	21.60 (2.00)	19.51 (1.59)	20.09 (1.87)	21.19 (1.11)	
Middle-high	28.46 (2.63)	30.55 (2.13)	29.72 (1.91)	34.70 (2.31)	30.81 (1.23)	
High	34.67 (2.86)	41.71 (2.54)	44.49 (2.18)	36.21 (2.48)	40.25 (1.62)	
Education						< 0.001
≤ Elementary	8.26 (1.34)	4.26 (0.69)	3.66 (0.58)	6.56 (1.15)	5.23 (0.46)	
Middle school	9.83 (1.56)	5.55 (0.79)	7.62 (1.00)	7.16 (1.14)	7.29 (0.58)	
High school	36.73 (2.62)	41.25 (2.02)	35.07 (1.99)	41.45 (2.43)	38.52 (1.29)	
≥ College	45.18 (2.74)	48.95 (2.10)	53.66 (2.23)	44.83 (2.52)	48.96 (1.52)	
Occupation						< 0.001
Unemployed	26.53 (2.17)	24.50 (1.65)	26.66 (1.61)	39.49 (2.12)	30.71 (0.98)	
Employed	73.47 (2.17)	75.50 (1.65)	73.34 (1.61)	60.51 (2.12)	73.15 (0.98)	
Subjective health status						< 0.001
Very good	5.17 (1.21)	4.52 (0.78)	4.31 (0.79)	3.09 (0.73)	4.26 (0.40)	
Good	21.16 (2.09)	31.33 (2.00)	29.27 (1.54)	27.72 (2.03)	28.16 (0.90)	
Moderate	53.74 (2.65)	53.45 (2.05)	55.59 (1.80)	54.20 (2.25)	54.35 (1.08)	
Bad	17.15 (1.91)	10.23 (1.27)	9.79 (1.17)	12.47 (1.55)	11.74 (0.73)	
Extremely bad	2.78 (0.70)	0.48 (0.21)	1.03 (0.36)	2.53 (0.75)	1.48 (0.24)	
Alcohol intake[1)]						0.302
Yes	54.26 (2.50)	58.36 (1.91)	53.53 (1.98)	54.70 (2.21)	55.32 (1.07)	
Smoking status[2)]						0.312
Yes	19.67 (2.07)	17.80 (1.59)	16.30 (1.37)	15.16 (1.60)	17.07 (0.83)	
Physical activity[3)]						0.822
Active	45.45 (2.50)	43.00 (1.85)	43.39 (1.90)	44.86 (1.99)	43.94 (1.03)	
Body mass index (kg/m^2)	24.62 ± 0.20***	24.05 ± 0.12*	23.68 ± 0.12	23.47 ± 0.15	23.90 ± 0.07	< 0.001
Obesity degree[4)]						0.003
Underweight	2.91 (0.95)	2.52 (0.55)	3.21 (0.68)	3.63 (0.85)	3.05 (0.67)	
Normal	31.33 (2.34)	38.34 (2.02)	39.73 (1.72)	42.78 (2.17)	38.55 (1.03)	
Overweight	23.14 (2.30)	23.02 (1.85)	26.86 (1.67)	22.80 (1.93)	24.24 (0.99)	
Obese	42.63 (2.65)	36.12 (1.75)	30.20 (1.78)	30.80 (2.09)	34.17 (0.99)	
Recognition of stress						< 0.001
Very much	7.75 (1.46)	3.09 (0.76)	2.76 (0.59)	3.18 (0.81)	3.79 (0.43)	
Much	30.63 (2.57)	23.95 (1.94)	19.88 (1.50)	17.30 (1.59)	22.35 (0.91)	
Little	51.10 (2.65)	60.26 (2.09)	66.32 (1.78)	63.97 (2.18)	61.46 (1.12)	
Rarely	10.52 (1.65)	12.70 (1.26)	11.04 (1.19)	15.55 (1.70)	12.40 (0.73)	
Obstructive sleep apnea						0.138
Yes	0.20 (0.20)	1.20 (0.48)	0.97 (0.41)	0.33 (0.24)	1.37 (0.23)	
Prediabetes[5)]	60.58 (2.84)	56.62 (1.99)	47.96 (1.98)	50.61 (2.13)	53.20 (1.16)	< 0.001
Fasting glucose (mg/dL)	96.95 ± 0.50*	96.00 ± 0.38	95.49 ± 0.37	95.28 ± 0.38	95.84 ± 0.22	0.034
HbA1c (%)	5.63 ± 0.01***	5.61 ± 0.01**	5.57 ± 0.01	5.58 ± 0.01	5.60 ± 0.01	< 0.001
Insulin (IU/mL)	9.06 ± 0.62*	7.84 ± 0.21	7.64 ± 0.18	7.72 ± 0.19	7.96 ± 0.14	0.140
HOMA-IR[6)]	2.21 ± 0.15*	1.90 ± 0.06	1.83 ± 0.05	1.85 ± 0.05	1.92 ± 0.03	0.077

Values are expressed as % (SE) or means ± SE. All the estimates were produced by the complex sample analysis, using integrated sample weight, to represent the Korean population.

P-values were calculated using χ^2 tests and a general linear model.

HbA1c, glycated hemoglobin; HOMA-IR, homeostasis model assessment of insulin resistance.

**P* < 0.05, ***P* < 0.01, ****P* < 0.001, Dunnett's test was performed for comparisons between the two groups (reference: 7–7.9 h).

1)Alcohol intake: ≥ 1 drink/month in the past year, yes

2)Smoking status: Current smoker, yes.

3)Physical activity: Practiced physical activity of mid intensity over 2.5 h per week or of high intensity or mid and high mixed intensity over 1.25 h per week (1 min of high-intensity physical activity is equal to 2 min of mid-intensity physical activity), active.

4)Obesity degree: Underweight, BMI < 18.5 kg/m^2; Normal, 18.5 kg/m^2 ≤ BMI < 23 kg/m^2; Overweight, 23 kg/m^2 ≤ BMI < 25 kg/m^2; Obese, BMI ≥ 25 kg/m^2.

5)Prediabetes: Fasting blood glucose between 100 to 125 mg/dL or 5.7% ≤ HbA1c ≤ 6.4%.

6)HOMA-IR: Glucose × Insulin/405.

Daily food and nutrient intake of the participants

Table 2 shows the food intake of the participants according to sleep duration. The mean total food intake was significantly lower in the < 6 h (1,531.34 ± 34.97 g, $P < 0.05$) and ≥ 8 h sleep duration groups (1,547.99 ± 28.14 g, $P < 0.05$) than in the 7–7.9 h reference group (1,638.94 ± 26.09 g, $P = 0.035$). Although most food groups did not show statistically significant differences across sleep duration categories, the intake of nuts per 1,000 g of total food intake was significantly lower in the < 6 h sleep duration group (3.71 ± 0.50 g) than in the 7–7.9 h group (5.05 ± 0.68 g, $P < 0.01$). The intake of plant oil per 1,000 g of total food intake was significantly lower in the < 6 h (3.59 ± 0.21 g, $P < 0.05$) and ≥ 8 h sleep duration groups (3.70 ± 0.20 g, $P < 0.05$) than in the 7–7.9 h reference group (4.26 ± 0.17 g). Additionally, the intake of potatoes per 1,000 g of total food intake was significantly higher (26.20 ± 2.56 g, $P < 0.05$) and the intake of milk per 1,000 g of total food intake was significantly lower (46.51 ± 3.25 g, $P < 0.05$) in the 6–6.9 h sleep duration group than in the 7–7.9 h reference group (19.83 ± 1.52 g and 55.22 ± 3.26 g, respectively).

Table 3 shows the nutritional intake of the participants according to sleep duration. The mean total energy intake was lower in the < 6 h and 6–6.9 h sleep duration groups than in the 7–7.9 h sleep duration group ($P = 0.007$). Fat intake per 1,000 kcal was lower in the ≥ 8 h sleep duration group than in the 7–7.9 h sleep duration group ($P = 0.048$). However, we found no differences in the intake of other nutrients between the groups.

KHEI of the participants

Table 4 shows the KHEI of the participants according to sleep duration. The total KHEI score was significantly lower in the < 6 h, 6–6.9 h, and ≥ 8 h sleep duration groups than in the 7–7.9 h sleep duration group ($P < 0.001$). The adequacy and breakfast scores were lower in the < 6 h sleep duration group than in the 7–7.9 h sleep duration group ($P < 0.001$ and $P = 0.002$, respectively). Meat, fish, eggs, and legumes score was lower in the < 6 h, 6–6.9 h, and ≥ 8 h sleep duration groups than in the 7–7.9 h sleep duration group ($P = 0.003$).

Table 2. Food intakes of the participants according to sleep duration category

Variables	Sleep duration				Total (n = 2,934)	*P*-value
	< 6 h (n = 497)	6–6.9 h (n = 847)	7–7.9 h (n = 941)	≥ 8 h (n = 649)		
Total food (g)	1,531.34 ± 34.97*	1,576.17 ± 27.56	1,638.94 ± 26.09	1,547.99 ± 28.14*	1,569.04 ± 15.24	0.035
Grain (g/1,000 g total intake)	189.79 ± 5.64	188.95 ± 4.47	185.66 ± 3.99	195.46 ± 5.21	188.22 ± 2.48	0.460
Potato (g/1,000 g total intake)	25.12 ± 3.20	26.20 ± 2.56*	19.83 ± 1.52	25.42 ± 2.50	24.10 ± 1.16	0.068
Sugars (g/1,000 g total intake)	5.79 ± 0.59	5.83 ± 0.48	5.86 ± 0.44	5.35 ± 0.47	5.79 ± 0.24	0.823
Beans (g/1,000 g total intake)	27.67 ± 2.97	28.26 ± 2.39	23.51 ± 1.52	28.96 ± 2.76	26.39 ± 1.26	0.132
Nuts (g/1,000 g total intake)	3.71 ± 0.50**	4.48 ± 0.61	5.95 ± 0.68	4.73 ± 0.83	4.87 ± 0.37	0.060
Vegetable (g/1,000 g total intake)	220.50 ± 6.48	215.27 ± 4.56	211.06 ± 3.89	204.77 ± 5.84	210.35 ± 2.89	0.224
Mushroom (g/1,000 g total intake)	4.46 ± 0.66	4.44 ± 0.61	4.72 ± 0.45	4.43 ± 0.56	4.64 ± 0.31	0.965
Fruit (g/1,000 g total intake)	102.33 ± 6.69	111.59 ± 5.32	103.42 ± 4.18	110.00 ± 5.63	107.91 ± 3.05	0.479
Seaweed (g/1,000 g total intake)	13.34 ± 2.06	20.05 ± 2.79	18.98 ± 1.93	16.36 ± 1.75	17.48 ± 1.12	0.137
Seasoning (g/1,000 g total intake)	23.38 ± 1.18	23.77 ± 0.80	23.61 ± 0.86	23.16 ± 0.77	23.51 ± 0.47	0.952
Plant oil (g/1,000 g total intake)	3.59 ± 0.21*	3.92 ± 0.18	4.26 ± 0.17	3.70 ± 0.20*	3.95 ± 0.10	0.053
Meat (g/1,000 g total intake)	67.75 ± 3.61	64.78 ± 3.11	71.56 ± 3.21	66.48 ± 3.46	68.03 ± 1.74	0.491
Egg (g/1,000 g total intake)	25.78 ± 2.11	24.93 ± 1.27	25.15 ± 1.41	23.98 ± 1.64	25.08 ± 0.81	0.916
Fish (g/1,000 g total intake)	62.34 ± 4.55	64.34 ± 3.28	67.90 ± 2.84	70.89 ± 4.28	65.54 ± 1.78	0.527
Milk (g/1,000 g total intake)	55.03 ± 5.29	46.51 ± 3.25*	55.22 ± 3.26	53.21 ± 4.76	54.13 ± 2.02	0.195
Animal fat (g/1,000 g total intake)	0.15 ± 0.04	0.17 ± 0.04	0.22 ± 0.07	0.12 ± 0.04	0.19 ± 0.03	0.638
Beverage (g/1,000 g total intake)	121.48 ± 8.71	115.45 ± 5.25	119.37 ± 5.08	113.11 ± 7.47	120.66 ± 3.60	0.848
Alcohols (g/1,000 g total intake)	47.16 ± 6.43	50.58 ± 4.91	53.05 ± 4.99	48.85 ± 5.24	48.50 ± 2.74	0.874

Values are expressed as means ± SE. All the estimates were produced by complex sample analysis, using integrated sample weight, to represent the Korean population adjusted for age and sex.
P-values were calculated using a general linear model.
*$P < 0.05$, **$P < 0.01$, Dunnett's test was performed for comparisons between the two groups (reference: 7–7.9 h).

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Table 3. Nutritional intakes of the participants according to sleep duration category

Variables	Sleep duration				Total (n = 2,934)	*P*-value
	< 6 h (n = 497)	6–6.9 h (n = 847)	7–7.9 h (n = 941)	≥ 8 h (n = 649)		
Energy (kcal)	1,839.96 ± 34.87**	1,868.48 ± 24.75**	1,957.12 ± 22.72	1,889.18 ± 29.46	1,870.06 ± 15.26	0.007
% energy of carbohydrate	62.49 ± 0.54	62.13 ± 0.45	61.05 ± 0.42	62.56 ± 0.53	61.76 ± 0.27	0.071
% energy of protein	15.30 ± 0.23	15.29 ± 0.15	15.78 ± 0.15	15.61 ± 0.22	15.51 ± 0.10	0.109
% energy of fat	22.21 ± 0.45	22.48 ± 0.37	23.17 ± 0.36	21.83 ± 0.40	22.73 ± 0.22	0.071
Protein (g/1,000 kcal)	36.64 ± 0.57	36.61 ± 0.37	37.85 ± 0.36	37.19 ± 0.46	37.20 ± 0.23	0.080
Fat (g/1,000 kcal)	23.70 ± 0.49	24.03 ± 0.38	24.69 ± 0.37	23.19 ± 0.41**	24.26 ± 0.23	0.048
Carbohydrate (g/1,000 kcal)	151.30 ± 1.50	150.45 ± 1.30	147.82 ± 1.24	151.40 ± 1.50	149.83 ± 0.75	0.152
Total dietary fiber (g/1,000 kcal)	15.12 ± 0.26	15.47 ± 0.24	14.76 ± 0.19	14.78 ± 0.23	15.00 ± 0.13	0.081
Sugar (g/1,000 kcal)	34.10 ± 0.91	33.18 ± 0.72	32.10 ± 0.57	32.82 ± 0.79	33.23 ± 0.40	0.236
Calcium (mg/1,000 kcal)	290.69 ± 7.11	275.30 ± 5.22	282.84 ± 4.97	273.83 ± 5.85	281.21 ± 2.93	0.223
Phosphorus (mg/1,000 kcal)	573.29 ± 6.85	572.99 ± 5.53	585.25 ± 4.93	574.70 ± 6.31	578.40 ± 3.23	0.315
Iron (mg/1,000 kcal)	5.25 ± 0.11	5.25 ± 0.09	5.21 ± 0.09	5.10 ± 0.11	5.21 ± 0.05	0.704
Sodium (mg/1,000 kcal)	1,805.30 ± 39.37	1,781.39 ± 27.39	1,807.74 ± 27.27	1,791.97 ± 37.07	1,789.89 ± 16.90	0.892
Potassium (mg/1,000 kcal)	1,568.91 ± 23.28	1,585.91 ± 23.32	1,543.03 ± 18.03	1,544.88 ± 21.50	1,563.29 ± 11.71	0.450
Vitamin A (ugRAE/1,000 kcal)	223.47 ± 8.22	212.12 ± 6.15	219.7 ± 5.81	209.27 ± 6.74	218.00 ± 3.68	0.437
Thiamin (mg/1,000 kcal)	0.627 ± 0.02	0.61 ± 0.01	0.62 ± 0.01	0.60 ± 0.01	0.61 ± 0.01	0.239
Riboflavin (mg/1,000 kcal)	0.869 ± 0.02	0.86 ± 0.01	0.86 ± 0.01	0.84 ± 0.01	0.86 ± 0.01	0.478
Niacin (mg/1,000 kcal)	6.48 ± 0.12	6.56 ± 0.10	6.66 ± 0.09	6.54 ± 0.11	6.60 ± 0.06	0.634
Vitamin C (mg/1,000 kcal)	37.55 ± 2.34	40.98 ± 2.16	39.50 ± 2.50	37.36 ± 1.98	39.52 ± 1.22	0.588

Values are expressed as means ± SE. All the estimates were produced by complex sample analysis, using integrated sample weight, to represent the Korean population adjusted for age and sex.
P-values were calculated using a general linear model.
**$P < 0.01$, Dunnett's test was performed for comparisons between the two groups (reference: 7–7.9 h).

Table 4. KHEI of the participants according to sleep duration category

Variables	Sleep duration				Total (n = 2,934)	*P*-value
	< 6 h (n = 497)	6–6.9 h (n = 847)	7–7.9 h (n = 941)	≥ 8 h (n = 649)		
Total KHEI score (0–100)	58.95 ± 0.64***	61.14 ± 0.45*	62.65 ± 0.43	60.98 ± 0.53*	61.14 ± 0.28	< 0.001
Component of KHEI score						
Adequacy	29.36 ± 0.51***	31.16 ± 0.38*	32.30 ± 0.36	30.49 ± 0.50**	31.04 ± 0.25	< 0.001
Have breakfast (0–10)	6.50 ± 0.22***	7.28 ± 0.16	7.39 ± 0.14	6.95 ± 0.19	7.01 ± 0.10	0.002
Mixed grains intake (0–5)	1.90 ± 0.10	1.90 ± 0.07	2.02 ± 0.08	1.95 ± 0.10	1.92 ± 0.05	0.723
Total fruits intake (0–5)	2.10 ± 0.11	2.31 ± 0.08	2.27 ± 0.08	2.22 ± 0.09	2.27 ± 0.05	0.448
Fresh fruits intake (0–5)	2.27 ± 0.12	2.56 ± 0.09	2.59 ± 0.09	2.52 ± 010	2.54 ± 0.05	0.190
Total vegetable intake (0–5)	3.58 ± 0.08	3.63 ± 0.06	3.69 ± 0.05	3.50 ± 0.07	3.57 ± 0.03	0.129
Vegetable intake excluding Kimchi and pickled vegetables intake (0–5)	3.22 ± 0.09	3.29 ± 0.07	3.41 ± 0.06	3.16 ± 0.07	3.27 ± 0.04	0.058
Meat, fish, eggs, and beans intake (0–10)	6.84 ± 0.16***	7.15 ± 0.11*	7.50 ± 0.10	7.14 ± 0.14*	7.21 ± 0.06	0.003
Milk and milk products intake (0–10)	2.94 ± 0.20	3.04 ± 0.19	3.44 ± 0.17	3.06 ± 0.22	3.24 ± 0.10	0.161
Moderation	19.88 ± 0.30	20.11 ± 0.21	20.19 ± 0.23	20.42 ± 0.26	20.13 ± 0.14	0.591
Sodium intake (0–10)	6.96 ± 0.15	6.96 ± 0.12	6.74 ± 0.11	6.91 ± 0.15	6.98 ± 0.07	0.475
Percentage of energy from saturated fatty acid (0–10)	6.88 ± 0.22	6.96 ± 0.15	7.01 ± 0.16	7.37 ± 0.16	6.97 ± 0.09	0.214
Percentage of energy from sweets and beverages (0–10)	6.04 ± 0.19	6.19 ± 0.15	6.45 ± 0.13	6.14 ± 0.17	6.18 ± 0.09	0.208
Energy balance	9.75 ± 0.24	9.88 ± 0.18	10.15 ± 0.15	10.07 ± 0.19	9.97 ± 0.09	0.406
Percentage of energy from carbohydrate (0–5)	2.85 ± 0.11	2.89 ± 0.09	2.94 ± 0.07	2.92 ± 0.09	2.91 ± 0.05	0.900
Percentage of energy intake from fat (0–5)	3.70 ± 0.09	3.65 ± 0.08	3.83 ± 0.07	3.79 ± 0.08	3.74 ± 0.04	0.249
Energy intake (0–5)	3.19 ± 0.12	3.33 ± 0.08	3.38 ± 0.08	3.36 ± 0.09	3.32 ± 0.04	0.602

Values are expressed as means ± SE. All the estimates were produced by complex sample analysis, using integrated sample weight, to represent the Korean population adjusted for age and sex.
P-values were calculated using a general linear model.
KHEI, Korean Healthy Eating Index.
*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$, Dunnett's test was performed for comparisons between the two groups (reference: 7–7.9 h).

Association of sleep duration and total KHEI score with prediabetes prevalence

Table 5 presents the ORs for prediabetes prevalence according to sleep duration and the quintile of the total KHEI score. Among the total participants, shorter sleep durations) were associated with a significantly higher risk of prediabetes compared with the reference

Table 5. Odds ratios for prediabetes by sleep duration category and the quintile of KHEI score

Variables	Model 1	Model 2	Model 3
Sleep duration			
Total			
< 6 h	1.594 (1.187–2.140)**	1.469 (1.076–2.004)*	1.447 (1.062–1.970)*
6–6.9 h	1.370 (1.109–1.692)**	1.321 (1.057–1.651)*	1.312 (1.050–1.640)*
7–7.9 h (Ref.)	1	1	1
≥ 8 h	1.119 (0.875–1.430)	1.154 (0.899–1.483)	1.146 (0.892–1.474)
Men			
< 6 h	1.492 (0.974–2.284)	1.380 (0.878–2.170)	1.375 (0.875–2.160)
6–6.9 h	1.499 (1.045–2.150)*	1.381 (0.947–2.012)	1.377 (0.945–2.007)
7–7.9 h (Ref.)	1	1	1
≥ 8 h	1.043 (0.702–1.550)	1.006 (0.663–1.528)	1.005 (0.662–1.526)
Women			
< 6 h	1.617 (1.141–2.290)**	1.567 (1.092–2.248)*	1.515 (1.059–2.166)*
6–6.9 h	1.265 (0.956–1.674)	1.228 (0.916–1.647)	1.213 (0.904–1.627)
7–7.9 h (Ref.)	1	1	1
≥ 8 h	1.231 (0.911–1.663)	1.322 (0.967–1.808)	1.300 (0.950–1.779)
Quintile of KHEI score			
Total			
Q5 (Ref.)	1	1	1
Q1	1.351 (1.036–1.761)*	1.266 (0.946–1.693)	1.253 (0.935–1.679)
Men			
Q5 (Ref.)	1	1	1
Q1	1.215 (0.761–1.941)	1.145 (0.687–1.908)	1.130 (0.674–1.895)
Women			
Q5 (Ref.)	1	1	1
Q1	1.535 (1.107–2.127)*	1.508 (1.062–2.141)*	1.471 (1.034–2.093)*

Values are expressed as odds ratio (95% confidence interval).
Prediabetes: Fasting blood glucose between 100 to 125 mg/dL or 5.7% ≤ HbA1c ≤ 6.4%.
Model 1: Adjusted for age and sex of the total participants or age in both men and women; Model 2: Model 1 + adjusted for household income level, education level, occupation level, stress recognition, body mass index, and total energy intake; Model 3: Model 2 + adjusted for the KHEI score in the sleep duration category or sleep duration level in the quintile of the KHEI score.
KHEI, Korean Healthy Eating Index; HbA1c, glycated hemoglobin.
*P < 0.05, **P < 0.01.

group (7–7.9 h). In Model 1, which adjusted for age and sex, the OR for prediabetes was 1.594 (95% CI, 1.187–2.140; P < 0.01) for the < 6 h group and 1.370 (95% CI, 1.109–1.692; P < 0.01) for the 6–6.9 h group. These associations remained significant after further adjustments for socioeconomic factors, BMI, and total energy intake in Model 2, and when additionally adjusted for the KHEI score in Model 3, the ORs were 1.447 (95% CI, 1.062–1.970; P < 0.05) and 1.312 (95% CI, 1.050–1.640; P < 0.05) for the < 6 h and 6–6.9 h groups, respectively.

In the sex-specific analyses, men who slept 6–6.9 h had a significantly higher risk of prediabetes in Model 1 (OR, 1.499; 95% CI, 1.045–2.150; P < 0.05), although this association was not significant in Models 2 and 3. In women, those who slept < 6 h had a significantly higher risk of prediabetes across all models, with the strongest association observed in Model 1 (OR, 1.617; 95% CI, 1.141–2.290; P < 0.01), which remained significant in Model 2 (OR, 1.567; 95% CI, 1.092–2.248; P < 0.05) and Model 3 (OR, 1.515; 95% CI, 1.059–2.166; P < 0.05).

All the participants in the lowest KHEI quintile (Q1) had a significantly higher risk of prediabetes compared with those in the highest quintile (Q5) in Model 1 (OR, 1.351; 95% CI, 1.036–1.761; P < 0.05). However, after adjusting for additional factors in Models 2 and 3, this association was no longer statistically significant. In the sex-specific analyses, the association was stronger in women. Women in KHEI Q1 had a significantly higher risk of prediabetes than that had by those in Q5 across all models (Model 1: OR, 1.535; 95% CI, 1.107–2.127; P

< 0.05; Model 2: OR, 1.508; 95% CI, 1.062–2.141; $P < 0.05$; and Model 3: OR, 1.471; 95% CI, 1.034–2.093; $P < 0.05$). No significant association was found in men across any models.

Association of the KHEI score by sleep duration with prediabetes prevalence

Table 6 presents the ORs for prediabetes according to the quintile of the KHEI score, stratified by sleep duration categories. In the total participants, those in the KHEI Q1 who slept 7–7.9 h had a significantly higher risk of prediabetes than that had by those in the KHEI Q5 (Model 1: OR, 1.775; 95% CI, 1.072–2.939; $P < 0.05$; Model 2: OR, 1.731; 95% CI, 1.040–2.882; $P < 0.05$). This association was not significant in participants with sleep durations of < 6 h, 6–6.9 h, or ≥ 8 h.

In the sex-specific analyses, women in the KHEI Q1 who slept < 6 h had a significantly higher risk of prediabetes than that had by those in the KHEI Q5 in Model 1 (OR, 2.601; 95% CI, 1.012–6.687; $P < 0.05$). This association remained significant in Model 2 after adjusting for additional factors (OR, 3.699; 95% CI, 1.240–11.040; $P < 0.05$). However, no significant associations between KHEI quintiles and prediabetes risk were observed in women who slept 6–6.9 h, 7–7.9 h, or ≥ 8 h or in men across the sleep duration category.

DISCUSSION

Using secondary data, we examined the relationship between diabetes indicators according to sleep duration and diet quality assessed using the KHEI among middle-aged adults aged 40–64 yrs and individuals with normal blood glucose levels or prediabetes, excluding those diagnosed with diabetes. The results revealed that women had longer sleep duration than that had by men, and there were differences in general characteristics such as income level, education, obesity, and perceived stress levels across sleep duration groups. In our analysis, participants in the 7–7.9 h sleep duration group was the reference group. Individuals in the short sleep duration group exhibited significantly higher blood glucose and HbA1c levels and significantly lower energy intake and diet quality, as measured by the KHEI score. We also analyzed the associations between sleep duration, KHEI scores, and prediabetes. The results showed that participants with adequate sleep duration (approximately 7–7.9 h) and higher KHEI scores had a significantly lower risk of prediabetes than that had by those with inadequate sleep duration and lower KHEI scores. In particular, the risk of prediabetes in women was higher when sleep duration was less than 6 h and the KHEI score was low.

Table 6. Odds ratios for prediabetes according to the quintile of the KHEI score by sleep duration category

Quintile of KHEI score	Sleep duration			
	< 6 h	6–6.9 h	7–7.9 h	≥ 8 h
Total, Q1 vs. Q5 (Ref.)				
Model 1	1.822 (0.849–3.906)	0.904 (0.544–1.502)	1.775 (1.072–2.939)*	1.197 (0.690–2.078)
Model 2	1.369 (0.563–3.330)	0.696 (0.382–1.267)	1.731 (1.040–2.882)*	1.067 (0.568–2.007)
Men, Q1 vs. Q5 (Ref.)				
Model 1	1.006 (0.318–3.179)	1.036 (0.456–2.353)	1.828 (0.774–4.319)	1.008 (0.368–2.762)
Model 2	0.723 (0.188–2.776)	0.771 (0.271–2.196)	2.110 (0.840–5.299)	1.604 (0.429–5.997)
Women, Q1 vs. Q5 (Ref.)				
Model 1	2.601 (1.012–6.687)*	1.095 (0.578–2.076)	1.560 (0.848–2.872)	1.315 (0.649–2.667)
Model 2	3.699 (1.240–11.040)*	0.959 (0.438–2.098)	1.490 (0.792–2.804)	0.906 (0.401–2.047)

Values are expressed as odds ratio (95% confidence interval).
Prediabetes: Fasting blood glucose between 100 to 125 mg/dL or 5.7% ≤ HbA1c ≤ 6.4%.
Model 1: Adjusted for age and sex of the total participants or age in both men and women; Model 2: Model 1+adjusted for household income level, education level, occupation level, stress recognition, body mass index, and total energy intake. *$P < 0.05$.

The average sleep duration for men and women in our study was 6.50 ± 0.04 h and 6.64 ± 0.03 h, respectively, with women having a significantly higher average sleep duration than that had by men (not shown in the table). This is consistent with previous studies that reported significant differences in sleep duration according to sex [32,33]. In this study, general characteristics such as the degree of obesity, income level, occupation, and perceived stress levels differed across the sleep duration groups. Sleep duration is closely associated with obesity, as short sleep duration induces changes in hormones such as leptin and ghrelin, which regulate appetite and contribute to increased appetite and food intake [3,19]. Short sleep duration has been reported to have a significant positive correlation with low income [34-36]. This is because low-income individuals are mostly blue-collar workers, which may lead to irregular working rhythms and long working hours [37]. Additionally, increased sleep duration was significantly associated with perceived stress levels. Sleep restriction results in increased sleepiness, fatigue, and stress, with a significant increase in cortisol and thyrotropin levels [38]. This supports the finding that perceived stress levels were higher in the short sleep duration group than in the other groups.

Therefore, it is difficult to draw general conclusions regarding the relationship between sleep duration and energy intake. Some studies have demonstrated an association between short sleep duration and increased caloric consumption [39,40]; however, another study conducted on adults in Switzerland with an average age of 58.3 yrs found no significant association between energy intake and sleep duration [41]. Conversely, a study performed on adult women in China showed a significant positive association between sleep duration and total energy intake [42]. In this study, compared with the reference group of 7–7.9 h sleep duration, both the group with < 6 h and 6–6.9 h sleep durations had significantly lower energy intake. Regression analysis of sleep duration and energy intake adjusted for age and sex (not shown) revealed a significant positive association. A potential mechanism by which inadequate sleep may increase food intake involves changes such as the elevation of key appetite hormones (e.g., leptin, ghrelin, and cortisol). However, several experimental studies on ad libitum feeding under free-living conditions have reported inconsistent changes in appetite hormones [43,44]. More in-depth and detailed research on the positive association between sleep duration and total energy intake observed in the current study is clearly needed.

Consuming a balanced diet provides the body with all the necessary nutrients for daily living. A proper diet is a balanced diet that does not have an excess or a deficiency of specific nutrients and includes adequate micronutrient intake. Therefore, to improve diet quality, it is important to consume a variety of foods containing essential nutrients in sufficient amounts. Moreover, breakfast is a primary source of energy for daily activities and is associated with the regulation of circadian rhythms [45]. However, because of busy schedules, the frequency of breakfast consumption has been decreasing in modern diets. As of 2022, the prevalence of skipping breakfast among Korean adults aged 19 yrs and older was 37.8%, showing an increasing trend compared with 24.6% in 2012 [10]. According to a study by Kant and Graubard [46] conducted in adults aged 20 yrs and older, the total number of eating episodes and snack frequency were not related to sleep duration, whereas short sleepers tended to have lower food intake during breakfast and dinner. Skipping breakfast may disrupt the circadian rhythm, and fasting until noon, followed by the lack of glucose intake, may trigger an increased risk of insulin resistance, leading to decreased beta-cell responsiveness and memory, and decreased and delayed insulin response after lunch [47,48]. These findings demonstrate that decreasing breakfast consumption and skipping breakfast, induced by short sleep periods, may pose a greater risk of prediabetes; therefore, eating healthy breakfast should be encouraged.

Epidemiological studies have described a significant relationship between short sleep duration and poor dietary quality [49,50]. According to Grandner *et al.* [51], compared with those who sleep for 7–8 h, individuals with shorter sleep durations tend to consume a smaller variety of foods. Moreover, Kant and Graubard [46] reported that individuals with short or long sleep duration had a significantly lower proportion of energy intake from proteins than that of normal-duration sleepers. In our study, compared with the 7–7.9 h sleep group, the short- and long-sleep duration groups had significantly lower scores for meat, fish, eggs, and beans. This result is consistent with previous reports [52,53] that showed an association of better sleep quality with frequent consumption of meat, eggs, and other similar foods, attributing to the positive effects of protein, zinc, omega-3 fatty acids, and other nutrients found in these food groups on sleep outcomes. However, we did not find a significant relationship between vegetable and fruit consumption and the amount of sleep reported in this study. Therefore, the relationship between fruit and vegetable consumption and sleep duration is yet to be elucidated [8,42]. Nevertheless, considering previous research on the positive impact of fruit and vegetable consumption on glycemic control in patients with type 2 diabetes patients [54], the effects of fruit and vegetable intake on blood glucose levels and insulin resistance among short sleepers require further investigation.

There has been insufficient study directly addressing the mechanism of the relationship between sleep duration and diet on prediabetes. This is because diets can affect sleep quality and sleep duration, but can also affect food choices depending on factors related to sleep, and the relationship between the 2 can be affected by sex, socioeconomic factors, and psychological factors [21,22,55,56]. Recently, Zhang *et al.* [22] reported in a study of patients with diabetes that sleep disorder and unhealthy eating habits can lead to the occurrence and development of diabetes, but also showed that BMI can act as an intermediate factor. In this study, the risk of prediabetes was significantly higher when the KHEI score was low even with an appropriate sleep time of 7–7.9 h in the total participants, and in the results of sex-specific analyses, the risk of prediabetes was significantly higher in women when the sleep duration was less than 6 h and the KHEI score was low. Although fully interpreting the results of this study based on prior studies is difficult, these findings will be helpful in analyzing the effects of sleep and diet on diabetes in more details in the future.

This study has several limitations. First, the cross-sectional nature of the data used in this study precludes causal inferences. Second, except for sleep duration as an independent variable, other sleep measurements, including sleep efficiency, sleep latency, and wake after sleep onset were not considered in this study. Future studies analyzing the relationship between diet quality and chronic diseases using indicators other than sleep duration are needed. We were also unable to discuss the effects of hormones such as leptin and ghrelin on sleep and dietary intake. In addition, the KHEI used in this study is calculated from dietary data examined using the 24-h recall method, but this method is limited by its difficulty to sufficiently reflect an individual's usual intake.

Despite these limitations, this is the first study to analyze the impact of sleep duration and dietary quality on prediabetes in Koreans. Our findings, using the KHEI developed considering the Korean diet and composed of items related to food group intake, provide baseline data for dietary guidelines for diabetes prevention. In addition, this study excluded individuals already diagnosed with diabetes among the study participants. We aimed to identify significant factors related to sleep duration and diet quality in the prediabetic stage from a prevention perspective.

In conclusion, this study showed a significant negative correlation between the KHEI score and risk of prediabetes in the 7–7.9 h sleep duration group among middle-aged Koreans. Our findings suggest that achieving the sleep duration of 7–-7.9 h and good diet are associated with the lowest risk of prediabetes. We recommend that the results of this study be used to educate adults aged 40–64 yrs on diet and lifestyle habits to prevent diabetes. Further in-depth studies investigating the effects of various sleep-related indicators and diet quality on the risk of chronic diseases are required.

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REFERENCES

1. Covassin N, Singh P. Sleep duration and cardiovascular disease risk: epidemiologic and experimental evidence. Sleep Med Clin 2016;11:81-9. PUBMED | CROSSREF
2. Grandner MA, Seixas A, Shetty S, Shenoy S. Sleep duration and diabetes risk: population trends and potential mechanisms. Curr Diab Rep 2016;16:106. PUBMED | CROSSREF
3. Bacaro V, Ballesio A, Cerolini S, Vacca M, Poggiogalle E, Donini LM, Lucidi F, Lombardo C. Sleep duration and obesity in adulthood: an updated systematic review and meta-analysis. Obes Res Clin Pract 2020;14:301-9. PUBMED | CROSSREF
4. Bock JM, Vungarala S, Covassin N, Somers VK. Sleep duration and hypertension: epidemiological evidence and underlying mechanisms. Am J Hypertens 2022;35:3-11. PUBMED | CROSSREF
5. Xie J, Li Y, Zhang Y, Vgontzas AN, Basta M, Chen B, Xu C, Tang X. Sleep duration and metabolic syndrome: an updated systematic review and meta-analysis. Sleep Med Rev 2021;59:101451. PUBMED | CROSSREF
6. Svensson T, Saito E, Svensson AK, Melander O, Orho-Melander M, Mimura M, Rahman S, Sawada N, Koh WP, Shu XO, et al. Association of sleep duration with all- and major-cause mortality among adults in Japan, China, Singapore, and Korea. JAMA Netw Open 2021;4:e2122837. PUBMED | CROSSREF
7. Grandner MA. Sleep, health, and society. Sleep Med Clin 2022;17:117-39. PUBMED | CROSSREF
8. Hirshkowitz M, Whiton K, Albert SM, Alessi C, Bruni O, DonCarlos L, Hazen N, Herman J, Adams Hillard PJ, Katz ES, et al. National Sleep Foundation's updated sleep duration recommendations: final report. Sleep Health 2015;1:233-43. PUBMED | CROSSREF
9. U.S. Centers for Disease Control and Prevention. Sleep: Getting enough sleep [Internet]. Atlanta (GA): U.S. Centers for Disease Control and Prevention; [cited 2024 February 9]. Available from: https://www.cdc.gov/sleep/about/index.html#cdc_behavioral_basics_quick-getting-enough-sleep.
10. Ministry of Health and Welfare, Korea Disease Control and Prevention Agency. Korea Health Statistics 2022: Korea National Health and Nutrition Examination Survey (KNHANES IX-1). Cheongju: Korea Disease Control and Prevention Agency; 2023.
11. Korean Diabetes Association. Diabetes Fact Sheet in Korea 2022. Seoul: Korean Diabetes Association; 2023.
12. U.S. Centers for Disease Control and Prevention. Diabetes risk factors [Internet]. Atlanta (GA): U.S. Centers for Disease Control and Prevention; 2024 [cited 2024 August 25]. Available from: https://www.cdc.gov/diabetes/risk-factors/index.html.
13. Spiegel K, Leproult R, Van Cauter E. Impact of sleep debt on metabolic and endocrine function. Lancet 1999;354:1435-9. PUBMED | CROSSREF
14. Liu Y, Wheaton AG, Chapman DP, Croft JB. Sleep duration and chronic diseases among U.S. adults age 45 years and older: evidence from the 2010 Behavioral Risk Factor Surveillance System. Sleep (Basel) 2013;36:1421-7. PUBMED | CROSSREF
15. Shan Z, Ma H, Xie M, Yan P, Guo Y, Bao W, Rong Y, Jackson CL, Hu FB, Liu L. Sleep duration and risk of type 2 diabetes: a meta-analysis of prospective studies. Diabetes Care 2015;38:529-37. PUBMED | CROSSREF

16. Jang JH, Kim W, Moon JS, Roh E, Kang JG, Lee SJ, Ihm SH, Huh JH. Association between sleep duration and incident diabetes mellitus in healthy subjects: a 14-year longitudinal cohort study. J Clin Med 2023;12:2899. PUBMED | CROSSREF
17. Broussard JL, Ehrmann DA, Van Cauter E, Tasali E, Brady MJ. Impaired insulin signaling in human adipocytes after experimental sleep restriction: a randomized, crossover study. Ann Intern Med 2012;157:549-57. PUBMED | CROSSREF
18. Dashti HS, Scheer FA, Jacques PF, Lamon-Fava S, Ordovás JM. Short sleep duration and dietary intake: epidemiologic evidence, mechanisms, and health implications. Adv Nutr 2015;6:648-59. PUBMED | CROSSREF
19. St-Onge MP, Roberts AL, Chen J, Kelleman M, O'Keeffe M, RoyChoudhury A, Jones PJ. Short sleep duration increases energy intakes but does not change energy expenditure in normal-weight individuals. Am J Clin Nutr 2011;94:410-6. PUBMED | CROSSREF
20. Nedeltcheva AV, Scheer FA. Metabolic effects of sleep disruption, links to obesity and diabetes. Curr Opin Endocrinol Diabetes Obes 2014;21:293-8. PUBMED | CROSSREF
21. Gangwisch JE, Hale L, St-Onge MP, Choi L, LeBlanc ES, Malaspina D, Opler MG, Shadyab AH, Shikany JM, Snetselaar L, et al. High glycemic index and glycemic load diets as risk factors for insomnia: analyses from the Women's Health Initiative. Am J Clin Nutr 2020;111:429-39. PUBMED | CROSSREF
22. Zhang Y, Wang Y, Zhang S, Zhang Y, Zhang Q; China National Diabetic Chronic Complications Study Group. Complex association among diet styles, sleep patterns, and obesity in patients with diabetes. Diabetes Metab Syndr Obes 2023;16:749-67. PUBMED | CROSSREF
23. Kweon S, Kim Y, Jang MJ, Kim Y, Kim K, Choi S, Chun C, Khang YH, Oh K. Data resource profile: the Korea National Health and Nutrition Examination Survey (KNHANES). Int J Epidemiol 2014;43:69-77. PUBMED | CROSSREF
24. Akiyama T, Yamakawa T, Orime K, Suzuki J, Sakamoto R, Matsuura-Shinoda M, Shigematsu E, Takahashi K, Kaneshiro M, Asakura T, et al. Sleep duration and food intake in people with type 2 diabetes mellitus and factors affecting confectionery intake. J Diabetes Investig 2023;14:716-24. PUBMED | CROSSREF
25. Korea Disease Control and Prevention Agency. Guide to the Utilization of the Data from the Eighth the Korean National Health and Nutrition Examination Survey (KNHANES VIII 1, 2). Cheongju: Korea Disease Control and Prevention Agency; 2023.
26. Lee G, Choi HY. Factors associated with dietary control and physical activity in the management of metabolic syndrome in Korean menopausal women. Int J Environ Res Public Health 2020;17:6901. PUBMED | CROSSREF
27. World Health Organization. The Asia-Pacific Perspective: Redefining Obesity and Its Treatment. International Obesity Task Force. Brussels: World Health Organization; 2000.
28. Masoodian SM, Omidifar A, Moradkhani S, Asiabanha M, Khoshmirsafa M. HOMA-IR mean values in healthy individuals: a population-based study in Iranian subjects. J Diabetes Metab Disord 2022;22:219-24. PUBMED | CROSSREF
29. Korean Diabetes Association. Clinical Practice Guidelines for Diabetes. Seoul: Korean Diabetes Association; 2023.
30. Rural Development Administration, National Institute Agricultural Sciences. Korean Food Composition Table, 9th ed. Wanju: Rural Development Administration, National Institute Agricultural Sciences; 2016.
31. Yook SM, Park S, Moon HK, Kim K, Shim JE, Hwang JY. Development of Korean Healthy Eating Index for adults using the Korea National Health and Nutrition Examination Survey data. J Nutr Health 2015;48:419-28. CROSSREF
32. Basner M, Spaeth AM, Dinges DF. Sociodemographic characteristics and waking activities and their role in the timing and duration of sleep. Sleep (Basel) 2014;37:1889-906. PUBMED | CROSSREF
33. Chen X, Wang R, Zee P, Lutsey PL, Javaheri S, Alcántara C, Jackson CL, Williams MA, Redline S. Racial/ethnic differences in sleep disturbances: the Multi-Ethnic Study of Atherosclerosis (MESA). Sleep (Basel) 2015;38:877-88. PUBMED | CROSSREF
34. Whinnery J, Jackson N, Rattanaumpawan P, Grandner MA. Short and long sleep duration associated with race/ethnicity, sociodemographics, and socioeconomic position. Sleep (Basel) 2014;37:601-11. PUBMED | CROSSREF
35. Ryu SY, Kim KS, Han MA. Factors associated with sleep duration in Korean adults: results of a 2008 community health survey in Gwangju metropolitan city, Korea. J Korean Med Sci 2011;26:1124-31. PUBMED | CROSSREF
36. Chen X, Wang SB, Li XL, Huang ZH, Tan WY, Lin HC, Hou CL, Jia FJ. Relationship between sleep duration and sociodemographic characteristics, mental health and chronic diseases in individuals aged from 18 to 85 years old in Guangdong province in China: a population-based cross-sectional study. BMC Psychiatry 2020;20:455. PUBMED | CROSSREF

37. Wang S, Li B, Wu Y, Ungvari GS, Ng CH, Fu Y, Kou C, Yu Y, Sun HQ, Xiang YT. Relationship of sleep duration with sociodemographic characteristics, lifestyle, mental health, and chronic diseases in a large Chinese adult population. J Clin Sleep Med 2017;13:377-84. PUBMED | CROSSREF
38. Baek Y, Jung K, Lee S. Effects of sleep restriction on subjective and physiological variables in middle-aged Korean adults: an intervention study. Sleep Med 2020;70:60-5. PUBMED | CROSSREF
39. Grandner MA, Kripke DF, Naidoo N, Langer RD. Relationships among dietary nutrients and subjective sleep, objective sleep, and napping in women. Sleep Med 2010;11:180-4. PUBMED | CROSSREF
40. Patterson RE, Emond JA, Natarajan L, Wesseling-Perry K, Kolonel LN, Jardack P, Ancoli-Israel S, Arab L. Short sleep duration is associated with higher energy intake and expenditure among African-American and non-Hispanic white adults. J Nutr 2014;144:461-6. PUBMED | CROSSREF
41. Marques-Vidal P, Schaller R, Vollenweider P, Waeber G, Guessous I, Haba-Rubio J, Heinzer R. The association between objective sleep duration and diet. The CoLaus|HypnoLaus study. Clin Nutr ESPEN 2022;48:313-20. PUBMED | CROSSREF
42. Tu X, Cai H, Gao YT, Wu X, Ji BT, Yang G, Li H, Zheng W, Shu XO. Sleep duration and its correlates in middle-aged and elderly Chinese women: the Shanghai Women's Health Study. Sleep Med 2012;13:1138-45. PUBMED | CROSSREF
43. Bosy-Westphal A, Hinrichs S, Jauch-Chara K, Hitze B, Later W, Wilms B, Settler U, Peters A, Kiosz D, Muller MJ. Influence of partial sleep deprivation on energy balance and insulin sensitivity in healthy women. Obes Facts 2008;1:266-73. PUBMED | CROSSREF
44. Schmid SM, Hallschmid M, Jauch-Chara K, Wilms B, Benedict C, Lehnert H, Born J, Schultes B. Short-term sleep loss decreases physical activity under free-living conditions but does not increase food intake under time-deprived laboratory conditions in healthy men. Am J Clin Nutr 2009;90:1476-82. PUBMED | CROSSREF
45. Wehrens SM, Christou S, Isherwood C, Middleton B, Gibbs MA, Archer SN, Skene DJ, Johnston JD. Meal timing regulates the human circadian system. Curr Biol 2017;27:1768-1775.e3. PUBMED | CROSSREF
46. Kant AK, Graubard BI. Association of self-reported sleep duration with eating behaviors of American adults: NHANES 2005-2010. Am J Clin Nutr 2014;100:938-47. PUBMED | CROSSREF
47. Jakubowicz D, Wainstein J, Landau Z, Raz I, Ahren B, Chapnik N, Ganz T, Menaged M, Barnea M, Bar-Dayan Y, et al. Influences of breakfast on clock gene expression and postprandial glycemia in healthy individuals and individuals with diabetes: a randomized clinical trial. Diabetes Care 2017;40:1573-9. PUBMED | CROSSREF
48. Ando H, Ushijima K, Yanagihara H, Hayashi Y, Takamura T, Kaneko S, Fujimura A. Clock gene expression in the liver and adipose tissues of non-obese type 2 diabetic Goto-Kakizaki rats. Clin Exp Hypertens 2009;31:201-7. PUBMED | CROSSREF
49. Kim S, DeRoo LA, Sandler DP. Eating patterns and nutritional characteristics associated with sleep duration. Public Health Nutr 2011;14:889-95. PUBMED | CROSSREF
50. Stern JH, Grant AS, Thomson CA, Tinker L, Hale L, Brennan KM, Woods NF, Chen Z. Short sleep duration is associated with decreased serum leptin, increased energy intake and decreased diet quality in postmenopausal women. Obesity (Silver Spring) 2014;22:E55-61. PUBMED | CROSSREF
51. Grandner MA, Jackson N, Gerstner JR, Knutson KL. Dietary nutrients associated with short and long sleep duration. Data from a nationally representative sample. Appetite 2013;64:71-80. PUBMED | CROSSREF
52. Lee YH, Chang YC, Lee YT, Shelley M, Liu CT. Dietary patterns with fresh fruits and vegetables consumption and quality of sleep among older adults in mainland China. Sleep Biol Rhythms 2018;16:293-305. CROSSREF
53. Lee YH, Chang YC, Liu CT, Shelley M. Evaluating the associations of consumption of non-red meat protein sources and flavor preferences on sleeping patterns among older adults in China. Sleep Biol Rhythms 2019;17:79-92. CROSSREF
54. Zin CA, Mohamed WM, Khan NA, Ishak WR. Effects of fruit and vegetable polyphenols on the glycemic control and metabolic parameters in type 2 diabetes mellitus: a review. Prev Nutr Food Sci 2022;27:257-64. PUBMED | CROSSREF
55. Vlahoyiannis A, Giannaki CD, Sakkas GK, Aphamis G, Andreou E. A systematic review, meta-analysis and meta-regression on the effects of carbohydrates on sleep. Nutrients 2021;13:1283. PUBMED | CROSSREF
56. Morselli L, Leproult R, Balbo M, Spiegel K. Role of sleep duration in the regulation of glucose metabolism and appetite. Best Pract Res Clin Endocrinol Metab 2010;24:687-702. PUBMED | CROSSREF